STATEMENT OF WORK

LOW WIND SPEED TURBINE PROJECT

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Background

In the United States, wind-generated electricity is generally competitive for a grid-connected application in locations with high-quality wind resources such as Class 6 wind sites (6.4 to 7.0 m/s annual-average wind speed at a height of 10 meters). Currently, the unsubsidized cost of wind energy at Class 6 sites ranges from 4 to 5 cents/kWh. Although near-term development of these high-quality wind resources is expected, the limited availability of Class 6 sites, coupled with their distance from load centers and transmission facilities, will constrain U.S. wind energy development to a fraction of its potential.

To position wind energy for long-term growth, DOE will focus its effort for large (>100kW) systems on technology that will be competitive at Class 4 (5.6 to 6.0 m/s) and Class 5 (6.0 to 6.4 m/s) wind sites. This strategic objective will result in a twenty-fold increase in U.S. land areas suitable for wind energy development. Furthermore, the lower-wind-speed resource areas are generally closer to load centers. For example, Class 4 wind resource areas are, on average, closer to major load centers than Class 6 areas by almost a factor of five.

Achieving cost effectiveness at lower wind speeds will require technology improvements that build on lessons learned from ongoing wind energy public-private research and development partnerships. Investigation of promising technology under the DOE WindPACT (Wind Partnerships for Advanced Component Technology) project may yield new opportunities for development of advanced wind turbine architectures. The Low Wind Speed Turbine Project (LWT) will take advantage of these new opportunities by assisting industry partners in studying advanced concepts for utility-scale turbines incorporating the best ideas for achieving cost effectiveness at lower wind speeds. It will also build on the success of the DOE Next Generation Turbine (NGT) Development project scheduled to conclude in the 2003 time frame. At Class 6 sites, the NGT turbines are targeted to achieve a life-cycle cost of electricity (COE) of approximately 3.0 ¢/kWh. At Class 4 sites, they are expected to provide electricity at approximately 4.0 ¢/kWh.

The synergy between the WindPACT and LWT projects is noteworthy. WindPACT is intended to help DOE achieve its COE goals by conducting research on wind turbine components. The objectives are to:

- reduce the cost of wind energy through technology advancement,
- determine the probable size range of future utility-scale turbines in the U.S.,
- evaluate advanced concepts that are necessary to achieve the WindPACT objectives,
- identify and resolve obstacles that might block industry from embracing promising technology,
- design, fabricate, and test selected advanced components to prove their viability, and
- support the U.S. wind industry by transferring technology from DOE laboratories.

The first phase of the WindPACT studies is attempting to identify the technologies and components that hold the greatest promise for improved performance and reduced cost. A second phase will involve the detailed design, fabrication and testing of these advanced components. Under Phase 1, four scaling studies were completed and one rotor configuration study is underway. Under Phase 2, several rotor system and drive train design studies are underway. Interim reports for the drive train subcontracts will be completed early in calendar year 2002.

The WindPACT study results are highly applicable to the LWT project. The design conditions are based on Class 4 wind sites and the research has focused on issues that must be addressed to make these sites cost effective. These issues include very tall towers, extended rotors, onsite erection techniques, advanced blade materials and fabrication techniques, and lightweight high-efficiency drive trains. The timing of the LWT project was chosen to take advantage of the WindPACT preliminary results. Accordingly, all WindPACT studies are published on the NREL web site and can be electronically downloaded. Reports can be retrieved at http://www.nrel.gov/publications using the keyword "WindPACT" in the Abstract field. As new reports are completed, they will be published on this site.

The LWT project is focused on reducing COE through technology and manufacturing improvements. However, other factors such as aesthetics, noise, transportability, reliability, and maintainability must also be considered for future wind turbines. Therefore, the LWT project will take a broad view toward identifying configurations that have high potential for accelerating the production of wind-generated electricity.

GOAL AND OBJECTIVE

The goal of the LWT project is to partner with U.S. industry to develop technology that makes wind energy a competitive electricity supply option in the extensive Class 4 and 5 wind sites in the United States. The specific objective is to develop large wind turbine systems capable of producing electricity for 3.0 ¢/kWh at Class 4 wind sites by 2007.

GENERAL SCOPE OF WORK

Development of a new wind turbine that results from the best design practices and incorporates the latest technology must proceed in measured steps spanning several years. The LWT project encompasses this complete process. To encourage broad industry participation and to unveil the most promising ideas, the scope of work is designed to accommodate a range of related activities. The three anticipated areas of participation (Technical Areas) are Conceptual Design Study, Component Development, and LWT Prototype Development. Although an offeror may submit more than one response to the Request for Proposals, only one area of participation (Technical Area) may be proposed in each response. If selected for an award, the Subcontractor shall complete the specific scope of work associated with the chosen area of participation. Work tasks for the three Technical Areas are described below. For all Technical Areas, the Subcontractor shall estimate the COE using the methodology of Attachment C applied at the wind sites designated in Attachment D. Optimization of the LWT shall focus on a COE Design Site having an annual-average wind speed of 5.8 m/s at a height of 10 meters.

NREL possesses numerous testing facilities and capabilities. Information about these testing capabilities can be found at www.nrel.gov/wind/. However, these facilities are often engaged months and even years in advance. Offerors who wish to use these capabilities in the execution of their proposed work should identify the scope of the test within their Statement of Work. Cost proposals should include all of the offeror's associated time and costs for such tests. During negotiation of the subcontract, availability and scheduling of such tests will be determined.

WORK TASKS FOR TECHNICAL AREA 1 – CONCEPTUAL DESIGN STUDY

The scope of work for Conceptual Design Study requires the Subcontractor to examine and refine its proposed technical approach to achieving the LWT COE objective. The principal subcontract deliverable shall be a final report describing the conceptual design of a highly advanced, utility-scale wind turbine capable of operating competitively in low wind sites. The report shall describe the design studies conducted, including evaluation of innovative concepts suited for low-wind sites and the assessment of related technology and market issues. It will explain why the proposed concept is expected to achieve the COE objective and describe the projected performance, budget, and schedule for a full-scale turbine development effort. The Subcontractor shall then conduct a final review meeting at which the contents of the final report shall be presented to NREL reviewers.

Task 1 Final Report **Deliverable # 1**

The Subcontractor shall prepare a final report in which it describes the proposed concept and its projected impact on the cost of energy for the LWT. Guidance on the preparation of the Final Report is contained in Attachment A. One unbound paper copy plus a Microsoft Word electronic file shall be delivered to NREL as specified in the subcontract schedule.

Task 2 Final Review Meeting **Meeting #1**

The Subcontractor shall conduct a final review meeting at NREL in Golden, Colorado, as specified in the subcontract schedule. At this meeting, which shall be attended by the Subcontractor and important members of its project team, the contents of the Final Report shall be presented along with answers to questions previously asked of the Subcontractor by NREL.

WORK TASKS FOR TECHNICAL AREA 2 – COMPONENT DEVELOPMENT

The scope of work for Component Development involves the design, fabrication, and testing of a component or subsystem that is expected to improve the performance, reliability or cost of wind turbines suitable for low wind sites. For the purposes of the LWT project, a subsystem is defined as one or more components whose fabrication, assembly and/or operation are interrelated so as to perform a particular function in the operation of wind turbines. Candidates include, but are not limited to gearboxes, generators, rotor blades, towers, foundations, and power conditioning equipment. NREL does not wish to define candidate subsystems so restrictively as to discourage prospective offerors from proposing certain items. However, it does wish to focus an offeror's effort on a single component or subsystem, thereby bringing to bear sufficient resources to reduce risk and enhance the likelihood of success.

The project shall begin with the development by the Subcontractor of a Project Work Plan that describes the details of the subcontract effort and is intended to guide the work activities. The Subcontractor shall then design (and if justified by rigorous review), fabricate, test and evaluate a selected component or subsystem. It shall demonstrate, either through appropriate laboratory and field tests or through the application of generally accepted engineering practice, that the selected component or subsystem meets specified design criteria. At the conclusion of the project, the Subcontractor shall prepare a Final Report and conduct a Final Review Meeting.

Task 1 Project Work Plan — Deliverable #1

The Subcontractor shall develop a Project Work Plan that includes all of the details important to the subcontract effort and expands upon its Component Development proposal. As a minimum, the information described under the heading Development Plan in Attachment A shall be addressed. An example of a more elaborate development plan may be found in Reference LWT-1, which is appended to the RFP.

Task 2 Kickoff Meeting — Meeting #1

The Subcontractor shall conduct a kickoff meeting within ninety days of the subcontract award date. At this meeting, the Subcontractor shall convene its important team members and the NREL Technical Review Team. In addition to the draft Project Work Plan, the Subcontractor shall discuss all aspects of the subcontract effort that have preceded the Kickoff Meeting. After the draft Project Work Plan has been delivered and the Kickoff Meeting has been conducted, the Subcontractor shall revise the Plan in consultation with NREL.

Task 3 Component Design

The Subcontractor shall complete the design of the component or subsystem it is considering for use on the LWT. Stresses and deflections of critical load-bearing components shall be analyzed using finite element methods, and fatigue life calculations shall be performed for dynamically loaded components. Documentation of this effort shall include sketches, drawings, specifications, loads, calculated maximum and allowable stresses on the components and subsystems affected. By conducting appropriate analyses and performing necessary calculations, the Subcontractor shall estimate the effect that various alternatives would have on turbine performance, component capital cost, component replacement cost and O&M cost.

Task 4 Component Test Plan — Deliverable #2

The Subcontractor shall prepare a Component Test Plan to guide the testing of the component or subsystems it is considering for use on the LWT turbine. In consultation with NREL, the Subcontractor shall identify the items to be tested and the criteria by which they will be evaluated. The Component Test Plan

shall indicate the minimum performance qualifications that must be met for the component, and the tests shall be designed to evaluate the performance of the component compared to its qualification criteria. The Component Test Plan shall describe the tests to be performed, including the following information, as a minimum:

- a description of the component or subsystem to be tested,
- the rationale for why the tests are required,
- predicted performance based on calculations or other analyses,
- the test objectives and technical approach,
- the test matrix showing the number of test conditions and replicated runs,
- the test schedule, budget and labor requirements,
- a description of the facilities, equipment and instrumentation required to conduct the tests,
- a description of test procedures, including parameters to be controlled and how they will be controlled; parameters to be measured and instrumentation to measure them; calibration procedures to be used; recommended re-calibration interval; and maintenance of a test log,
- a description of the data analysis procedures,
- a description of quality assurance procedures,
- definition of the criteria that must be met for acceptance of the tested components,
- the Safe Operating Procedures (SOPs) necessary to protect employees, visitors and the environment from harm during all phases of testing, and
- contingency measures to be considered if the test objectives are not met.

Task 5 Component Design Review **Deliverable #3 and Meeting #2**

The Subcontractor shall conduct a review meeting at NREL to discuss the design of the component or subsystem it is considering for use on the LWT turbine. The meeting shall be attended by important members of the Subcontractor's design team and the NREL Technical Review Team. The Subcontractor or key members of its team shall present information that addresses the following topics.

- updated project status, including changes since last review,
- updated project schedule showing key milestones and deliverables,
- updated project cost summary,
- design philosophy and approach, including:
  - rationale for major design features,
  - techniques and sequence of analysis,
  - load cases considered, and
  - a description of control philosophy,
- engineering design, including:
  - tradeoff study results,
  - performance analysis methods and results,
  - component design loads,
  - structural analysis methods and results,
  - identification of critical risks, and
  - descriptive drawings of major components and subsystems,
- preliminary COE results and other figures of merit, if applicable,
- long-lead-time purchasing requirements, and
- anticipated tests of the component or subsystem.

To allow sufficient preparation time, multiple copies of a Component Design Review Package (Deliverable #3) summarizing this material shall be provided to NREL three weeks in advance of the meeting.

Task 6 Component Acquisition

After the Component Design Review, and only with NREL concurrence, the Subcontractor shall fabricate, purchase or otherwise acquire the component or subsystem to be tested. Sufficient quantities shall be obtained to assure successful completion of the planned tests. The components shall be acquired in a fashion as closely resembling commercial procurement practices as is reasonable under the circumstances.

Task 7 Component Testing

In accordance with the Component Test Plan developed in Task 4, the Subcontractor shall complete a qualification test program to ensure the suitability of the component or subsystem it is considering for use on the LWT. Test results shall be analyzed to determine if any changes are required in the design prior to its potential use. If necessary, the Subcontractor shall identify follow-on measures that are necessary to ensure the suitability of the component. Documentation of the component or subsystem test shall include the following information, as a minimum.

- the tests results,
- a description of any unusual occurrences during the tests, and
- additional analysis or tests that are anticipated.

Task 8 Analysis of Test Results

The Subcontractor shall thoroughly analyze the component or subsystem tests results and compare them to analytical predictions. If test results differ significantly from predictions, the Subcontractor shall evaluate why those differences exist. Consideration shall be given to potential problems with the testing process, the analytical methods, the input data to those methods, and conformity between the analytical models and tested component. If the predicted responses do not provide adequate safety factors or acceptable fatigue life, the Subcontractor shall propose appropriate remedial actions, such as de-rating the component, decreasing lifetime or redesigning critical parts. If necessary, the Subcontractor shall re-evaluate performance, cost and structural response information before making a final recommendation of the component or subsystem for use on the LWT.

Task 9 Final Report **Deliverable # 4**

The Subcontractor shall prepare a final report in which it describes the proposed component or subsystem and its projected impact on the cost of energy for the LWT. Guidance on the preparation of the Final Report is contained in Attachment A.

Task 10 Final Review Meeting **Meeting #3**

The Subcontractor shall conduct a final review meeting at NREL in Golden, Colorado, as specified in the subcontract schedule. At this meeting, which shall be attended by the Subcontractor and important members of its project team, the contents of the Final Report shall be presented along with answers to questions previously asked of the Subcontractor by NREL.

WORK TASKS FOR TECHNICAL AREA 3 – LWT PROTOTYPE DEVELOPMENT

The scope of work for LWT Prototype Development requires the Subcontractor to develop a wind turbine that achieves a combination of improved performance, increased reliability and decreased cost such that the COE objective is eventually met. Considerable emphasis is placed on engineering documentation, periodic reviews and extensive testing. This approach is intended to facilitate the eventual certification and deployment of the LWT through follow-on engineering and testing.

The project shall begin with the development by the Subcontractor of a Project Work Plan that describes the details of the subcontract effort and guides the activities. Work tasks shall include conceptual design (including tradeoff studies), preliminary design, component development and testing, detailed design, fabrication, and testing of a prototype wind turbine. The rotor diameter and rated power of the prototype shall be the same as that intended for commercial deployment. Attachment B lists the suggested requirements for the LWT Prototype Development Statement of Work. An example of a more elaborate development plan is contained in Reference LWT-1, which is appended to the RFP. That plan was used for a project having multiple phases and turbines. Although that approach is not intended for LWT Prototype Development, which is restricted to a single prototype, Reference LWT-1 is provided to illustrate the detailed planning required to accomplish complex turbine development projects.

Most of NREL's turbine development subcontracts have employed a statement of work that prescribes activities step-by-step through the completion of the project. Recent improvements in defining the certification process suggest an alternative approach for the LWT project. Working together, the Subcontractor and NREL will develop a mutually acceptable Statement of Work and Project Work Plan. There can be considerable flexibility in these documents, but the engineering process should be geared toward eventual certification of the LWT by an internationally recognized agency. This suggests that even in the early stages of development, engineering documentation and testing should be completed in accordance with established certification procedures, checklists, and guidelines. Consequently, although certification of the LWT prototype is not anticipated, the Subcontractor must provide design and test documentation in accordance with NREL certification guidelines.

A description of the certification process can be found in International Electrotechnical Commission (IEC) WTGS 01, *System for Conformity Testing and Certification of Wind Turbines – Rules and Procedures*. Certification requirements are defined in IEC 61400-1, *Wind Turbine Generator Systems – Part 1: Safety Requirements*. NREL has developed a series of procedures, checklists, and guidelines to assist manufacturers in coordinating their certification activities. The relevant documents will be made available to subcontractors through the NWTC web site. Selected excerpts, which may be useful in preparing LWT project proposals, are contained in Reference LWT-2, which is appended to the RFP.

REPORTING REQUIREMENTS

Distribution

The Subcontractor shall send to the NREL Project Manager one unbound paper copy and a Microsoft Word electronic file of all draft deliverables submitted for review. After revision and final approval, a Microsoft Word electronic file shall be sent to the NREL Project Manager and the NREL Subcontract Administrator. The addresses for delivery of reports and other correspondence are shown below.

National Renewable Energy Laboratory
National Wind Technology Center
1617 Cole Boulevard, MS3811
Golden, CO 80401
Attention: Neil Wikstrom

National Renewable Energy Laboratory
National Wind Technology Center
1617 Cole Boulevard, MS3811
Golden, CO 80401
Attention: (Project Manager to be determined)

Report Quality

Engineered products of high quality require engineering documentation of high quality. Therefore, the reports required under this subcontract are expected to comply with high standards for technical writing. These standards include logical organization, consistent formatting, completeness, conciseness, preciseness and grammatical correctness. To achieve this level of quality, the Subcontractor should plan, if necessary, to supplement its staff with consultants who are experts in the technical writing of engineering reports. The "Style Guide for NREL Subcontract Reports" is an example of acceptable style. Alternative styles and formats may be acceptable to NREL, if they meet the desired standards for quality.

Protected Wind Technology Data

NREL expects there will be two classes of data generated under this subcontract. The first represents data that NREL will require from the Subcontractor that will be available for dissemination to the public without restriction. The second represents data that the Subcontractor may be allowed to stamp as "Protected Wind Technology Data." A specific list of information that will be made available to the public will be negotiated and included in any resulting subcontract. The following list identifies those deliverables that are expected be available for dissemination to the public and those that will be protected.

Deliverables

The Subcontractor shall submit the following deliverables in accordance with the Statement of Work.

<u>Technical Area 1</u> – Conceptual Design Study Deliverables

1. Final Report (Volume 1 only)

<u>Technical Area 2</u> – Component Development Deliverables

1. Project Work Plan*
2. Component Test Plans *
3. Component Design Review Package *
4. Monthly Reports*
5. Final Report (Volume 1 and Volume 2*)

Technical Area 3– LWT Prototype Development Deliverables

The final statement of work for the LWT Prototype Development subcontract will be developed cooperatively by NREL and the Subcontractor. It is possible there will be meetings and deliverables that are not currently envisioned. However, in accordance with Attachment B, the Subcontractor should plan for the following deliverables.

1. Project Work Plan*
2. Baseline Turbine Description*
3. Preliminary Design Review Package *
4. Component Test Plans *
5. Field Test Plan* (in accordance with NREL certification guidelines)
6. Design Documents* (in accordance with NREL certification guidelines)
7. Final Report (Volume 1 and Volume 2*)
8. Scale Models
9. Monthly Reports*
10. Information for Public Distribution

Volume 1 of any Final Report, along with deliverables #8 and #10 shall be designated as "Data Available to the Public". All other deliverables, marked with an asterisk, may be designated as "Protected Wind Technology Data". However, it may be appropriate to disseminate portions of those deliverables in accordance with the guidelines provided in the subcontract. In this regard, NREL may request outside assistance in reviewing subcontract data as part of its technical review process, and to provide data for assessments of the DOE/NREL wind program.

Monthly Reports

For subcontracts issued in Technical Area 2, Component Development, and Technical Area 3, LWT Prototype Development, the Subcontractor shall submit brief monthly reports that document the progress its team has made toward completion of the project. Each report shall be approximately five pages in length and prepared in accordance with the format provided in Attachment E. Reports shall be submitted to the NREL Subcontract Administrator and the NREL Project Manager via electronic mail in a Microsoft Word electronic format. Monthly reports shall be delivered to NREL within fifteen (15) days of the end of each month. The Subcontractor shall identify the reports as deliverables with the company name, subcontract title and subcontract number clearly identified.

Monthly reports shall focus on accomplishments since the last report; problems or variances from planned activity, the completion of milestones, deliverables, meetings or other achievements. They shall also provide a summary labor report, cost report and schedule. The information shall be presented as follows.

- a summary of significant events occurring since the last report presented as a “bulleted” list of sentences or short paragraphs, and including (i) a statement of the percent complete for the project in comparison to the percent of the planned labor hours expended, and (ii) a statement of the cumulative costs for the project in comparison to the total authorized costs for the subcontract,
- a summary of analysis and test support provided by NREL since the last report,
- the outlook for the next two months presented as a “bulleted” list of anticipated significant events,
- a tabular summary of labor hours showing the task/subtask number and name, planned labor-hours, percent complete, earned labor-hours, actual (cumulative) labor-hours, percent of the planned labor hours expended and the sum of each of the labor-hour columns,

- a tabular summary of subcontract costs (using the same cost categories as the Subcontractor's Cost Proposal Form) for the report month and the cumulative costs for the subcontract, and
- a one-page, updated project schedule in bar-chart format, as originally supplied in the Project Work Plan, showing the percent complete for each project activity.

Information for Public Distribution

As noted above, some data produced under the subcontract will be available for dissemination to the public without restriction. Potential uses of the data include journal and magazine articles, conference papers, promotional brochures and audio-visual presentations describing the Subcontractor's project, or the wind energy program and its accomplishments. In these situations, the Subcontractor shall make a timely response in providing text, sketches, drawings, photographs and other descriptions of work performed under the Subcontract. The information shall be accompanied by permission to use the photographs and images in an unrestricted manner, including placement on the Internet.

Meetings

The Subcontractor shall conduct the following meetings in accordance with the Statement of Work. In addition to these formal meetings, informal design review meetings and test review meetings shall be conducted at the request of the NREL Project Manager or the Subcontractor.

Technical Area 1 – Conceptual Design Study Meetings

1. Final Review Meeting
2. DOE/NREL Subcontractor Review Meeting

Technical Area 2 – Component Development Meetings

1. Kickoff Meeting
2. Component Design Review
3. Final Review Meeting
4. DOE/NREL Subcontractor Review Meeting

Technical Area 3– LWT Prototype Development Meetings

The final statement of work for the LWT Prototype Development subcontract will be developed cooperatively by NREL and the Subcontractor. It is possible there will be meetings that are not currently envisioned. However, in accordance with Attachment B, the Subcontractor shall plan for the following meetings as a minimum.

1. Kickoff Meeting
2. Preliminary Design Review Meeting
3. Test Readiness Review Meeting
4. Final Review Meeting
5. DOE/NREL Subcontractor Review Meeting

DOE/NREL Subcontractor Reviews

The Subcontractor shall attend the DOE/NREL Subcontractor Review Meeting in each year the subcontract is in place. At these meetings, which are held in Golden, Colorado, the Subcontractor shall report on the status of the subcontract and the significant project results.

Critical Project Reviews

NREL will continually evaluate its portfolio of LWT technology. Therefore, Critical Project Reviews will be held periodically to determine the appropriate scope of work and level of support for various projects. This decision will be based upon technical accomplishments and programmatic issues. If a decision is made to proceed as planned, the Subcontractor shall advance to the next work activity. If a decision is made not to proceed, the Subcontractor shall continue to work only on final reporting. In general, performance of the subcontract and the attendant expenditures shall not proceed until NREL approval is received to do so after Critical Project Reviews. If the Subcontractor wishes to commit resources to long lead items before a Critical Project Review is successfully completed, it must make a formal request to the NREL Project Manager and receive authorization before proceeding.

The timing and nature of Critical Project Reviews may vary from one subcontract to another. However, for planning purposes, the Subcontractor shall anticipate that these reviews will occur annually.

NREL'S TECHNICAL ROLES

NREL has two technical roles in this project. One of these is to provide technical review and oversight. In this capacity, NREL will review engineering processes and documentation, evaluate the adequacy of engineering designs and test results, and make recommendations to the Subcontractor. Its involvement with analysis, design, fabrication and prototype test activities will be advisory only. NREL will also review and evaluate major technical decisions in an effort to ensure the prudent use of public funds.

NREL's second role is technical assistance. In this capacity, NREL will use its special capabilities to assist the Subcontractor in solving technical problems and completing work tasks. The Subcontractor may request engineering support in such areas as performance analysis, structural analysis, system-dynamic modeling, structural testing of blades, component and full-system modal testing, test planning and assistance. This support will be provided, with Subcontractor concurrence, as NREL resources permit.

ATTACHMENT A

GUIDANCE FOR PREPARATION OF FINAL REPORTS (CONCEPTUAL DESIGN STUDY OR COMPONENT DEVELOPMENT TECHNICAL AREA)

Description of Proposed Concept or Component

The Subcontractor shall describe its proposed concept or component in such a way that a reasonably knowledgeable wind-energy professional will be made aware of the important technical considerations. This description shall include the design philosophy and approach, rationale for major design features, and operational strategies considered. Innovation that represents noteworthy technological improvement, is essential to the success of the concept, requires extensive development effort, or presents significant risk shall be identified and discussed. The Subcontractor shall also address the advantages and disadvantages of its proposed concept compared to existing technology. The information presented should establish the technical merit, feasibility and rationale for development of the proposed concept.

The Subcontractor shall describe the studies it conducted to investigate influential design parameters, determine the effect of design choices on cost and performance, and provide guidance in defining a concept or component for further study. The following topics shall be addressed, as a minimum.

- design constraints, alternatives and configuration variables that were investigated,
- performance and structural analyses methods used,
- the effect of independent configuration variables on dependent figures-of-merit, such as reliability, maintainability, system lifetime and cost-of-energy, and
- estimated system performance as represented by tables and plots of electrical power output versus wind speed at the COE Reference Sites defined in Attachment C.

If appropriate, details of Component Development tests shall be provided, including as a minimum:

- description of the component tested (including changes made during the tests),
- description of facilities, equipment, instrumentation, test matrix, calibration and test procedures,
- test objectives, technical approach and data analysis procedures, and
- comparison of predicted and measured performance, loads and system dynamic response.

The Subcontractor shall discuss the reasons why it believes that progress toward the COE objective is achievable through implementation of the proposed concept or component. In doing so, it shall provide information on performance, capital cost, replacement cost and operations and maintenance cost. Economic figures-of-merit shall be estimated in accordance with the methodology described in Attachment C.

ATTACHMENT B

GENERIC STATEMENT OF WORK FOR LWT PROTOTYPE DEVELOPMENT

The scope of work for the LWT Prototype Development shall include conceptual design (including trade-off studies), preliminary design, component development and testing, detailed design, fabrication, and testing of a prototype wind turbine. The rotor diameter and rated power of the prototype turbine shall be the same as that selected for eventual commercial deployment. The information provided in the Offeror's proposal will be combined with NREL's technical and administrative requirements to develop a statement of work for the subcontract. An example wind turbine prototype development plan that has been used in the past is provided in Reference LWT-1, which is appended to the RFP. Although the Subcontractor is free to propose a work plan that suits its own preference, NREL will require a logical, systematic engineering approach that is likely to result in the achievement of the LWT project objectives. The following activities are suggested for inclusion in the Statement of Work.

- project planning, including:
  - preparation of a project work plan,
  - presentation of the work plan at a kickoff meeting,
  - ongoing maintenance of the work plan and other project management activities as required;
- conceptual design, an iterative process involving:
  - tradeoff studies,
  - performance and cost analyses,
  - definition of a baseline system as a point of departure for subsequent anlayses;
- preliminary design, inlcuding;
  - designs, drawings, and specifications,
  - performance, structural and cost analyses, and
  - design review;
- detailed design (component development), including:
  - component design,
  - component test plans,
  - component tests,
  - analysis of test results,
  - refined performance and cost analyses,
  - refined structural analysis, including fatigue life predictions,
  - full-system dynamic analysis, and
  - electrical/control system design;
- final design (systems integration), including:
  - designs, drawings and specifications,
  - refined performance, cost, and structural analyses,
  - prototype turbine test plan, and
  - design review;
- fabrication of a prototype wind turbine,
- testing of the prototype turbine, including:
  - site preparation,
  - turbine installation,
  - installation of test equipment,
  - test readiness review,
  - testing,
  - analysis of test results, and
  - validation of predictive methods;

- project reporting, including:
  - monthly reports,
  - design and test documentation in accordance with NREL certification guidelines,
  - design review meetings,
  - informal meetings, as required, and
  - final subcontract report;
- fabrication of two (1:40) scale models delivered to NREL soon after the prototype is defined, and
- final review.

ATTACHMENT C

COST OF ENERGY ANALYSIS FOR DESIGN TRADEOFF STUDIES

This attachment describes the assumptions and methods that shall be used to define and support the primary figure-of-merit for advanced wind turbines developed under the DOE/NREL Next Generation Low Wind Speed Turbine Project. The primary figure-of-merit, Cost of Energy (COE), is calculated using assumed wind conditions at two "Reference Sites" and economic parameters associated with a hypothetical Generation Company (GenCo) project utilizing corporate (balance sheet) financing. The calculation method presented below uses formulas to approximate the results of a detailed pro forma cash flow model used for commercial projects. NREL's Financial Analysis Tool for Electric Energy Projects (FATE2-P) was used to model a hypothetical GenCo project. In an attempt to standardize COE estimates, typical values for financial parameters (such as cost of capital and inflation rate) and fixed costs (such as insurance, property taxes and land lease) were chosen. These typical values reflect market conditions as of October 2001. The simplified calculation method presented herein provides a means to evaluate design alternatives on a comparative basis and develop data for NREL's wind program assessments. However, the method is not a reliable estimate of energy costs for planned or actual wind power plants.

Assumptions

The following assumptions shall be used to calculate the COE for two Reference Sites.

- Reference Site #1: representative of the Great Plains of the United States
  - 5.8 m/s annual average wind speed at a height of 10 m, Rayleigh distribution, vertical wind-shear exponent = 0.143
- Reference Site #2: representative of mountain ridge lines
  - 6.7 m/s annual average wind speed at a height of 10 m, Rayleigh distribution, vertical wind-shear exponent = 0.143
- Economic parameters: constant dollar COE in January 2002 dollars
- Fixed Charge Rate (constant dollar) = 11.85%
- Nominal (current dollar) discount rate = 9.25%
- Real (constant dollar) discount rate = 6.07%
- Turbine manufacturing volume: sufficient to produce 250 turbines per year, assuming prior production of 150 turbines
- Project Life = 30 years
- Plant size = 100 MW
- Capital Costs are in January 2002 dollars
- Plant start date = January 2003 (construction period is one year)
- Inflation = 3%
- Combined federal-state tax rate = 40%
- Land Lease Cost = $0.00108/kWh in year 2002 dollars

Cost of Energy

The primary figure-of-merit is the levelized cost of energy, which is to be provided in constant, January 2002 dollars. COE is calculated for a 100 MW (rated) wind power plant, with an expected life of 30 years, using the following equation:

$$COE = \frac{(FCR \times ICC)}{AEP_{net}} + AOE$$

where:

COE	≡	Levelized Cost of Energy ($/kWh) (constant dollar)	
FCR	≡	Fixed Charge Rate (constant dollar) (1/yr)	= (0.1158)
ICC	≡	Initial Capital Cost ($)	
AEP_{net}	≡	Net Annual Energy Production (kWh/yr)	
AOE	≡	Annual Operating Expenses	
	≡	$LLC + \frac{(O\&M + LRC)}{AEP_{net}}$	
LLC	≡	Land Lease Cost	
O&M	≡	Levelized O&M Cost	
LRC	≡	Levelized Replacement/Overhaul Cost	

Fixed Charge Rate

The Fixed Charge Rate is the annual amount per dollar of Initial Capital Cost needed to cover the capital cost, a return on debt and equity, and various other fixed charges. This rate is imputed from a hypothetical project, assuming GenCo balance sheet financing, modeled with NREL's FATE2-P pro forma cash flow spreadsheet model. Specifically, it includes construction financing, financing fees, return on debt and equity, depreciation, income tax, property tax and insurance. For the COE calculations, a constant dollar FCR = 0.1158 per year shall be used. The 10-year Section 45 Renewable Energy Production Tax Credit is not included in the Fixed Charge Rate and should not be included in the analysis.

Initial Capital Cost

The Initial Capital Cost is the sum of the Turbine System Cost and the Balance of Station Cost. Neither cost should include construction financing or financing fees, because these are calculated and added separately through the fixed charge rate. Neither cost should include a debt service reserve fund, which is assumed to be zero for balance sheet financing.

The Turbine System Cost shall be supported by a tabular listing of component costs and weights. Costs shall be based on a manufacturing volume of 250 turbines per year, assuming prior production of 150 turbines. In estimating the cost of components manufactured in-house, assembly labor and manufacturing overhead shall be included. Thus, the stated cost should be the same as that developed in a "buy/make" analysis. The following breakdown of component costs shall be used.

- rotor assembly
  - blades
  - aerodynamic control system
  - rotor hub
  - miscellaneous costs, including labor for factory assembly of rotor components
- nacelle assembly
  - low-speed shaft, bearings and couplings
  - gearbox
  - generator
  - mechanical brake system
  - mainframe (chassis)
  - yaw system, including drives, dampers, brakes and bearings
  - nacelle cover
  - work platform
  - miscellaneous costs, including labor for factory assembly of the nacelle

- tower (less on-site assembly costs included in "installation" below)
- control and electrical systems, including labor for factory assembly
- shipping costs, including permits and insurance
- warranty costs, including insurance
- mark-up, including royalties, profit and overhead not included above

The Balance of Station Cost shall be supported by a tabular listing of the costs shown below.

- wind resource assessment and feasibility studies
- surveying
- site preparation, including roads, grading and fences
- electrical collection system infrastructure
- substation
- foundations for the wind turbines
- O&M facilities and equipment
- receiving, installation, checkout and startup
- wind power plant control and monitoring equipment
- initial spare parts inventory
- permits and licenses
- legal counsel
- project management and engineering
- construction insurance
- construction contingency

Annual Operating Expenses

Land Lease Cost

Annual Operating Expenses include Land Lease Cost, Levelized O&M Cost, and Levelized Replacement/Overhaul Cost, all expressed in units of $/kWh. A levelized, constant-dollar land lease cost of $0.00108/kWh in year 2002 dollars shall be used. (The levelized, current-dollar value is $0.00146/kWh in year 2002 dollars.) This value was derived from a land lease term of 3% of revenues in the hypothetical GenCo case described. Because land lease payments are tax-deductible, the land lease cost specified above has already been multiplied by 60% (1 - 40%, where 40% is the combined tax rate).

Levelized O&M Cost

A component of AOE that is larger than the Land Lease Cost is O&M (Operations and Maintenance Cost). The O&M Cost shall include, and be supported by, a tabular listing of the following annual costs:

- labor, parts and supplies for scheduled turbine maintenance
- labor, parts and supplies for unscheduled turbine maintenance
- parts and supplies for equipment and facilities maintenance, and
- labor for administration and support

O&M should *not* include the land lease payment, which was included in the step above. O&M should *not* include property tax or insurance, as these are calculated separately and included with the Fixed Charge Rate. Because first-year O&M Cost is very close to the constant-dollar levelized expense, the first year value (in 2002 dollars) shall be used as a reasonable approximation of the levelized value. Because the first year of operation is 2003, if O&M cost is estimated in year 2003 dollars, it should be converted to 2002 dollars by dividing by 1.03 (1 + the rate of inflation). Because O&M is tax deductible, the final O&M value should be multiplied by 60% (1 – 40%, where 40% is the combined federal-state tax rate). Thus, the levelized O&M Cost calculation is:

$$O\&M = \frac{\text{First Year O\&M Cost (in 2002 dollars) x 0.60}}{AEP_{net}}$$

Levelized Replacement/Overhaul Cost

Levelized Replacement/Overhaul Cost distributes the cost of major replacements and overhauls over the life of the wind turbine. This cost shall be supported by a tabular listing of:

- the year in which each replacement or overhaul is required relative to the year of installation, and
- each replacement or overhaul cost including parts, supplies and labor, in current year dollars for the year of the replacement or overhaul

Downtime during replacements and overhauls shall be included in the determination of overall turbine availability. In the pro forma cash flow model, one "saves" for replacements and overhauls with deposits to a reserve fund in the years preceding the maintenance event. The repair is then depreciated using a straight-line convention. Consequently, both of these items – the major maintenance reserve fund and the repair depreciation – shall be incorporated into the calculation of Levelized Replacement/Overhaul Costs. To account for maintenance reserve fund payments, the following calculations shall be performed.

(1) Use the following equation to determine the Present Value of each stream of reserve fund deposits incurred for each discrete replacement and overhaul event:

$$PV(n) \equiv PVF(n_{midpoint}) \times RC(2002) \times 1.03^{n}$$

where:

$PV(n)$ ≡ Present Value of annual stream of reserve fund payments for event occurring in year (n)

$PVF(n_{midpoint})$ ≡ Present Value Factor for mid-point year of reserve fund payment stream $= (1 + i)^{-n_{midpoint}}$

i ≡ Nominal discount rate $= (0.0925)$

$RC(2002)$ ≡ Replacement/Overhaul Cost in year 2002 (in the formula above, 1.03^{n} is an inflation factor)

For example, if a replacement is made in year 10, the mid-point year ($n_{midpoint}$) is 5, because reserve fund payments are made from years 1 through 10. If second identical replacement follows in year 20, the mid-point year for that event is 15, because the reserve fund payments for that replacement were made from years 10 through 20. However, if replacement is made only in year 20, the mid-point year is 10.

(2) Calculate the Levelized Replacement/Overhaul Cost (in constant dollars) by multiplying the sum of present values of the reserve fund payment streams by the Capital Recovery Factor.

$$LRC = CRF \times \sum PV(n)$$

where:

CRF ≡ Capital Recovery Factor

≡ $i_{const}/(1-(1+i_{const})^{\wedge -30}$ $= (0.073)$

i_{const} ≡ Constant dollar discount rate $= (0.0607)$

(3) Multiply LRC by 0.80 to account for depreciation of each replacement (this factor was derived from the pro forma spreadsheet model described above)

Net Annual Energy Production

The Net Annual Energy Production shall be calculated for two Reference Sites, using wind-turbine performance specifications, estimated energy losses, and turbine availability. AEP calculations shall be supported by a tabular listing of the parameters shown below. Values in parentheses shall be used for the Reference Sites.

- Reference Site #1: annual average wind speed at a hub height of 10 m = (5.8 m/s)
- Reference Site #2: annual average wind speed at a hub height of 10 m = (6.7 m/s)
- vertical wind-shear exponent = (0.143)
- wind distribution table or specification = (Rayleigh)

Gross Annual Energy Production shall be calculated using the methodology described in the latest draft [1] of the International Electrotechnical Commission (IEC) Standard 1400-12. For calculations of COE, the wind speed range may be divided into 1.0 m/s bins rather than the IEC-specified 0.5 m/s bins. The following equations shall be used.

$$AEP_{gross} = N_h \sum_{i=1}^{N} [F(V_i) - F(V_{i+1})] [(P_i + P_{i+1}) / 2]$$

where:

AEP_{gross}	≡	Gross Annual Energy Production (kWh/yr/turbine)	
N_h	≡	number of hours in one year	= (8760)
N	≡	number of wind speed bins	
V_i	≡	wind speed in bin (i) (m/s)	
V_{i+1}	≡	wind speed in bin (i+1) (m/s)	
P_i	≡	power output in bin (i) (kW)	
P_{i+1}	≡	power output in bin (i+1) (kW)	
$F(V)$	≡	accumulated Rayleigh distribution	
	=	$1+ \exp [-\pi/4 \times (V/V_{hub, avg})^2]$	
V	≡	Actual wind speed (m/s)	
$V_{hub, avg}$	≡	Annual average wind speed at hub height (m/s)	
	=	$V_{10m, avg} \times (H_{hub} / 10)^{\alpha}$	
$V_{10m, avg}$	≡	annual average wind speed at the Reference Site (m/s)	
H_{hub}	≡	hub height (m)	
α	≡	vertical wind shear exponent	= (0.143)

Turbine Performance shall be tabulated as electrical power output at the bus bar versus wind speed at hub height. The table shall show power output for wind speeds from 0 to 25 m/s in 1.0 m/s increments starting with 0.5 m/s. If the table is based upon measurements, normalizations and averaging using the IEC methodology, it shall identify which bins include "measured" data (based on three, 10-minute data sets) and which bins are extrapolations of measured data. If the table is based on projected performance, the rotor configuration and analysis method (e.g. PROP) shall be clearly stated.

Net Annual Energy Production shall account for energy losses and availability as follows.

$$AEP_{net} = AEP_{gross} \times (1 - EL) \times \text{Availability}$$

where:

$EL \equiv$ product of individual energy losses (% losses expressed as a decimal)
$= 1 - (1 - L_{array}) \times (1 - L_{soiling}) \times (1 - L_{control}) \times (1 - L_{collect})$

$L_{array} \equiv$ Array losses

$L_{soiling} \equiv$ Blade soiling losses

$L_{control} \equiv$ Controls and miscellaneous losses

$L_{collect} \equiv$ Collection system losses from the turbines to the substation

Energy Losses and Availability shall be specified in a tabular listing. Availability is the ratio of the number of hours that the turbine was capable of operating during a certain period (excludes the number of hours that it could not operate because of maintenance or fault situations) to the total number of hours in the period.

References

1. *Wind Turbine Generator Systems - Part 12: Power Performance Measurement Techniques.* International Electrotechnical Commission (IEC), Technical Committee (TC) No. 88, Standard 1400-12, CDV Draft, February 8, 1994.

ATTACHMENT D

DESIGN WIND REGIMES

Using the methods described in Attachment C, the Subcontractor shall calculate the cost-of-energy (COE) at two wind regimes. The first is the COE Design Site[1] described below, which has a Rayleigh distribution of wind speeds with a 5.8 m/s annual average at a height of 10 meters. The second is the COE Reference Site[2] described below, which has a Rayleigh distribution of wind speeds with a 6.7 m/s annual average at a height of 10 meters. A third wind regime, the NREL Approved Structural Design Site, will either be prescribed by NREL or suggested by the subcontractor and subsequently approved by NREL. This shall be the primary wind regime for design load analyses in accordance with IEC guidelines.

	Percent of Time At Wind Speed		
Wind Speed Bin Center (m/s)	COE Design Site[1] 5.8 m/s	COE Reference Site[2] 6.7 m/s	Subcontractor-Selected Structural Design Site
0.5	2.31	1.73	___
1.5	6.61	5.02	___
2.5	10.04	7.81	___
3.5	12.22	9.85	___
4.5	13.04	11.01	___
5.5	12.63	11.30	___
6.5	11.30	10.84	___
7.5	9.41	9.79	___
8.5	7.35	8.40	___
9.5	5.41	6.86	___
10.5	3.75	5.35	___
11.5	2.46	3.99	___
12.5	1.53	2.85	___
13.5	0.90	1.96	___
14.5	0.51	1.29	___
15.5	0.27	0.82	___
16.5	0.14	0.50	___
17.5	0.07	0.29	___
18.5	0.03	0.16	___
19.5	0.01	0.09	___
20.5	0.01	0.05	___
21.5	0.00	0.02	___
22.5	0.00	0.01	___
23.5	0.00	0.01	___
24.5	0.00	0.00	
V_{ave} @ 10 m	V_{ave} = 5.8 m/s @ 10 m	V_{ave} = 6.7 m/s @ 10 m	V_{ave} = _____

The following equation shall be used to compute the wind speed as a function of height above the ground. For the COE Reference Sites, the wind shear exponent $\alpha = 0.143$. For the Design Site, the Subcontractor shall specify the wind shear exponent.

$$V(z) = V_{10m}\,(z/10m)^{\alpha}$$

Note that turbulence levels and extreme gust conditions used for design analyses are not described by the wind-speed probability distributions given above. These values shall be clearly defined by the Subcontractor and reported to NREL in appropriate deliverable reports.

ATTACHMENT E

MONTHLY REPORT FORMAT

SUBCONTRACTOR NAME

LOW WIND SPEEED TURBINE PROJECT

Subcontract No. AAA-xxx-yyy-zz

NREL Project Manager: (To Be Determined)
NREL Subcontract Administrator: Neil Wikstrom

Major Accomplishments for the Month of _____, 2002

- .....
- .....
- At the end of this month xx.x% of the project had been completed with yy.y% of the planned labor hours expended.
- Cumulative costs to date have been $xxx,xxx ($yyy,yyy = total subcontract)

NREL Analysis and Testing Support

- .....
- .....
- .....
- .....

Outlook for the Next Two Months

- .....
- .....
- .....
- .....

Table 1 - Tabular Labor Summary

WBS Number/Name (example shown below)	Planned Labor Hours[1]	Percent Complete[2]	Earned Labor Hours[3]	Actual Labor Hours[4]	Percent Expended[5]
1. Project Management					
2. Kickoff Meeting					
3. Component Design					
4. Component Test Plan					
5. Component Design Review					
6. Component Acquisition					
7. Component Testing					
8. Analysis of Test Results					
9. Final Report					
10. Final Review Meeting					
Total		(xx.xx)[6]			(yy.yy)[7]

1. From the Project Work Plan. Planned labor hours, which include lower-tier subcontractors and consultants, should not change after the Plan is approved by NREL.
2. From pre-determined milestones or estimates of percent complete for each subtask.
3. Computed as the product of planned labor hours and percent complete: Column (1) x Column (2).
4. Cumulative labor hours billed through this time period.
5. Computed as the actual labor hours divided by the planned labor hours: Column (4) ÷ Column (1).
6. Computed as the total earned labor hours divided by the total planned labor hours.
7. Computed as the total actual labor hours divided by the total planned labor hours.

Table 2 - Tabular Cost Summary

Cost Category	Month of	Cumulative
1. Direct Materials		
2. Material Overhead		
3. Direct Labor		
4. Labor Overhead & Fringe Benefits		
5. Equipment		
6. Travel		
7. Lower-Tier Subcontractors		
8. Consultants		
9. Other Direct Costs		
10. Total Direct Cost & Overhead		
11. General & Administrative Expense		
12. Facilities Capital Cost of Money		
13. Royalties		
14. Total Project Cost		
15. Subcontractor's Cost Share		
16. NREL's Cost Share		